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Case Report

Dramatic Failure of an OXINIUM Total Knee Arthroplasty With a Massive Pseudotumor Formation

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A B S T R A C T

Since the early 2000s, oxidized zirconium implants have emerged as a valuable option in total hip and knee arthroplasty due to their wear resistance and suitability for patients with metal hypersensitivity. The surface of these components is created through a heating and oxidation process of a zirconium alloy, resulting in a thin layer with favorable wear properties. However, there have been few reports of severe metallosis resulting from inadvertent wear of oxidized zirconium components through various mechanisms, including dissociation of the polyethylene liner and joint instability. We present a case involving a dramatic failure of an oxidized zirconium total knee arthroplasty, necessitating a staged revision arthroplasty.

Introduction

The most common late failure mode of total knee arthroplasty (TKA) is still aseptic loosening, frequently caused by frictional wear [1]. The use of alternative materials, the development of new implant surfaces, and the optimization of polyethylene properties are innovations of the last few decades aimed at reducing frictional wear and improving implant durability in TKA.

Oxidized zirconium (OXINIUM™, Smith & Nephew, Memphis, TN) implants for TKA and total hip arthroplasty have been available since the early 2000s. The material has a ceramicized surface created by a heating and oxidization process of zirconium alloy with favorable biomechanical properties and is used for manufacturing femoral components, too. This surface has a thickness of 5 μm and is more than twice as hard as cobalt-chromium (CoCr) alloys. In particular, the durability and abrasion resistance of the surface have been described as superior to conventional materials [2–4]. Registry data have shown equal long-term function and survival rates over 12 years compared with CoCr alloys [5]. These data, along with the usability for preexisting cobalt, nickel, and chromium hypersensitivity, have led to increased use in recent years.

However, progressive wear of implant surfaces and consecutive contact of metallic implant components can lead to massive metallosis. On the histologic level, the wear debris causes an inflammatory reaction initiated by macrophages and mediated by different inflammatory cells such as tumor necrosis factor-alpha, various interleukins, and others [6]. These adverse local tissue reactions can lead to the destruction of bony and soft-tissue structures [7] and not infrequently cause a significant increase in the technical demands of revision surgery. Adverse local tissue reactions due to polyethylene, CoCr, and titanium debris are now well-studied [8–10], whereas, apart from the fact that zirconium particles induce less-inflammatory reactions than titanium in vivo [11], little is known about side reactions to wear particles of oxidized zirconium.

This case report presents the failure of a tricompartmental TKA using a femoral OXINIUM component without implant loosening and a massive radiopaque pseudotumor formation 12 years after surgery, treated by a 3-staged revision arthroplasty. Written informed consent was obtained from the patient for the publication of this case report.

Case history

A 74-year-old female patient who underwent left cemented TKA in November 2010 presented at our clinic in June 2022 with a complaint of knee pain and swelling persisting for the past 6 months. The symptoms had no preceding trauma, and the pain was localized laterally, worsening during walking.

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The initial indication for surgery was knee osteoarthritis with a 12° valgus alignment. The TKA was performed in our department in 2010 using a cruciate-retaining design (Genesis II, Smith & Nephew, Memphis, TN) with the following components: femur size 6 OXINIUM; tibia size 5; polyethylene inlay 9-mm-deep flex; onlay patella 35 mm. An OXINIUM femoral component was used due to preexisting nickel hypersensitivity.

Postoperatively, we routinely perform regular clinical and radiological follow-ups after 3 months, 1, 2, 5, 10, and 15 years. At the 3-month postoperative visit, she reported some residual swelling but was overall satisfied with the outcome. Radiographs showed no signs of loosening or migration; the mechanical axis showed a residual 3° valgus alignment (Fig. 1). There were no further presentations or concerns regarding the left knee in subsequent years, neither at our clinic nor elsewhere.

During the clinical examination in June 2022, her weight was recorded as 105 kg with a height of 173 cm, resulting in a body mass index of 35 kg/m^2. The left knee did not exhibit any redness, warmth, or signs of infection, but there was general swelling, most pronounced over the lateral and dorsal aspect of the knee. No instability was observed in the anteroposterior direction, but there was a second-degree joint laxity in the mediolateral direction. The knee exhibited a valgus deviation, the range of motion was from 0° extension to 110° flexion.

Radiographs in 2 planes (Fig. 2) revealed a cloudy, radiopaque structure measuring approximately 5 × 8.5 cm dorsally to the femur. This structure also occupied the superior recessus, measuring approximately 9 × 12 cm. Additionally, contact between the femoral and tibial metal components in the lateral compartment, along with a groove on the lateral aspect of the femoral component, was visible. A long-leg radiograph showed a valgus alignment of 10°.

Joint aspiration yielded a bloody-grey fluid consistent with metallosis. The leukocyte count was 14,900/μl, with neutrophils accounting for 76% of the total. Fluid remained sterile after a long-term incubation of 14 days. The preoperative white blood cell count was 7.33 G/l (normal range: 4.3-10.8 G/l), and the C-reactive protein level was 6.71 mg/l (normal range: <6.0 mg/l).

Even though a periprosthetic infection seemed unlikely considering all the aforementioned findings, a staged revision was planned to prevent third-body wear due to the OXINIUM debris with metal and ceramic particles. We felt that a meticulous debridement of the anterior and the popliteal pseudotumor using an anteromedial and a posterior approach could not be performed

Figure 1. Radiographs of the left knee (anteroposterior, lateral, long leg stand) 5 days after primary TKA in 2010.

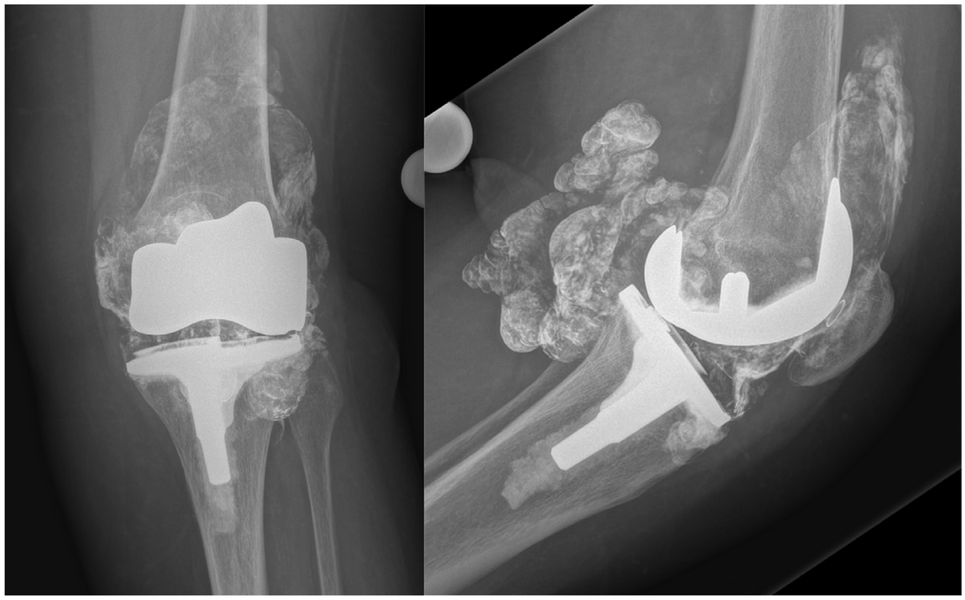

Figure 2. Radiographs taken during the patient's presentation in June 2022 revealed a substantial pseudotumor and metal-metal contact in the lateral compartment.

in a single procedure without taking inadequately high risks for perioperative complications.

The first surgery was conducted under regional anesthesia with sedation. Following a medial arthrotomy, the synovia appeared predominantly black. The polyethylene inlay showed posterior lateral wear down to the tibial plateau, which also exhibited slight wear at the posterior end (Fig. 3a-c). The femoral shield displayed a defect measuring 6 × 2 cm^2 with a depth of 0.3 mm (Fig. 4a). The lateral aspect of the inlay was abraded due to particle presence resulting from wear in the posterolateral corner (Fig. 4b), the tibial plateau itself revealed some slight damage. A complete synovectomy was performed, and the metal components were removed. A mobile polymethyl methacrylate spacer was implanted (Fig. 5), and samples were taken for microbiological and histopathological analysis.

The microbiological samples remained sterile after long-term incubation. The histopathological analysis indicated the presence of a wear particle-induced periprosthetic membrane (Krenn Type I) with significant evidence of black pigments consistent with metallic wear. No signs of infection or malignancy were observed.

In a second operation, performed 15 days after explantation, the remaining popliteal pseudotumor was addressed using a posterior approach and the macroscopically delimitable residual tumor was extracted. A postoperative radiograph showed an almost complete removal of the popliteal mass (Fig. 6).

After a subsequent interval of 4 weeks the spacer was removed, and a condylar-constrained revision TKA (Legion Revision System, Smith & Nephew, Memphis, TN) was implanted. The components used were as follows: femur revision size 4 OXINIUM, tibia revision - size 3, polyethylene-inlay 13-mm condylar constrained. For improved metaphyseal force transmission, a 22-mm short tibial cone was employed, along with femoral (120 × 16 mm) and tibial (120 × 12 mm) cemented stems for diaphyseal fixation. We opted for an OXINIUM component again to prevent third-body wear because of possible residual ceramic particles, even though a meticulous debridement was carried out and because of the hypersensitivity to nickel.

At the 3- and 12-month routine clinical and radiological checkups, the patient reported satisfaction without the need for any painkillers and exhibited good clinical function with full extension and flexion up to 120°. The knee joint demonstrated no signs of instability, with an initial residual mild general swelling and no signs of infection. Radiographs in 2 planes 1 year after reimplantation (Fig. 7) showed correct implant positioning without any signs of dislocation, malalignment, or component wear.

Discussion

The presented case highlights a rare but significant complication involving zirconium debris, resulting from metal contact between the OXINIUM femoral component and the tibial plateau made from titanium. This interaction leads to the formation of a large radiopaque pseudotumor, with the exact cause remaining elusive even 12 years postsurgery.

The first reports on specific complications related to OXINIUM components with a radiographic finding similar to our case, also described as an "OXINIUM arthrogram" by Frye et al. [12], were published due to liner dislocation in total hip arthroplasty [13–15] and unicompartmental knee arthroplasty [16,17]. Only a few reports are available describing TKA failure with OXINIUM components in combination with excessive polyethylene wear.

Recently, Kelly et al. [18] reported on a patient with bilateral TKA failure 5 years postoperatively with metal-on-metal contact and similar radiological findings. Significant obesity and recurrent falls were discussed as possible risk factors, leading to progressive instability. Once the hard oxidized layer of OXINIUM components is damaged, zirconium itself is a metal softer than titanium or CoCr [12,14]. This aspect may lead to a rapid progression of metallosis. Revision surgeries were performed using hinged implants with partial removal of the radiologically evident metallosis. In particular, the pseudotumor of the popliteal region was left in place. In our opinion, the risk of relevant third-body wear due to ceramic particles appears high, so in the present case, we endeavored to achieve the most complete extraction possible by means of an additional popliteal approach. However, it was not possible to achieve complete removal to eliminate the problem of third-body wear. At present, it is not possible to conclusively determine how much influence the remaining debris will have on wear behavior.

Kore et al. [19] reported a case with pronounced metallosis likewise 5 years after TKA. The authors discussed repetitive

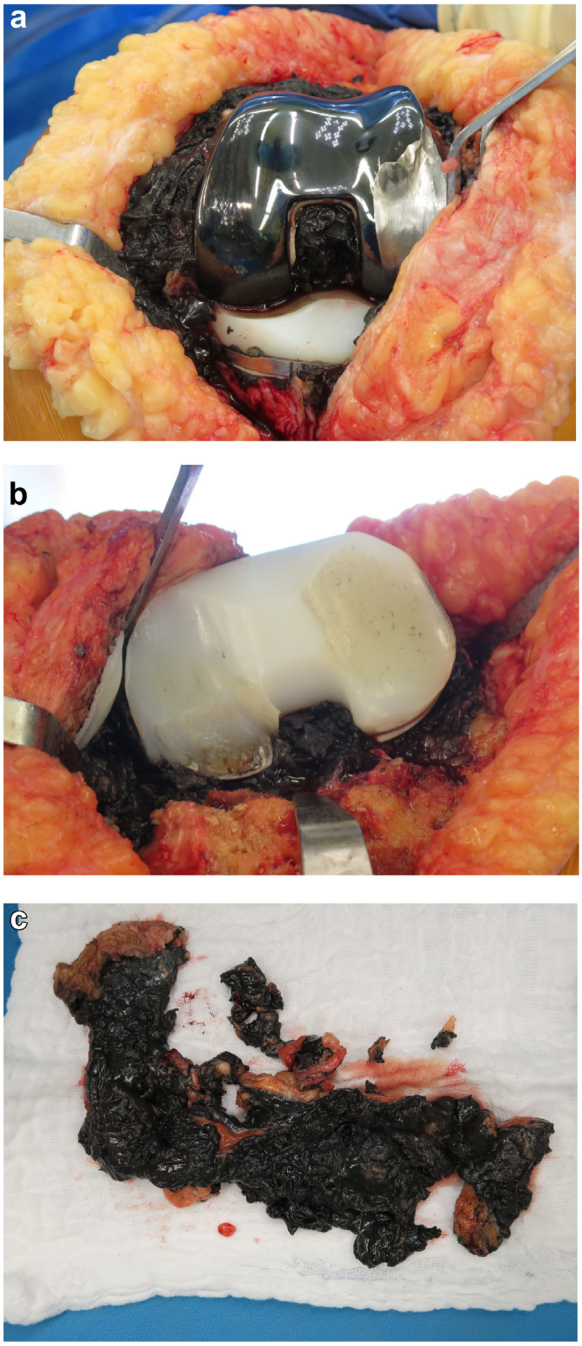

Figure 3. (a-c) Intraoperative images illustrating the abrasion of the lateral aspect of the femur shield, the posterolateral extensively worn polyethylene insert, and the synovial tissue displaying complete black pigmentation.

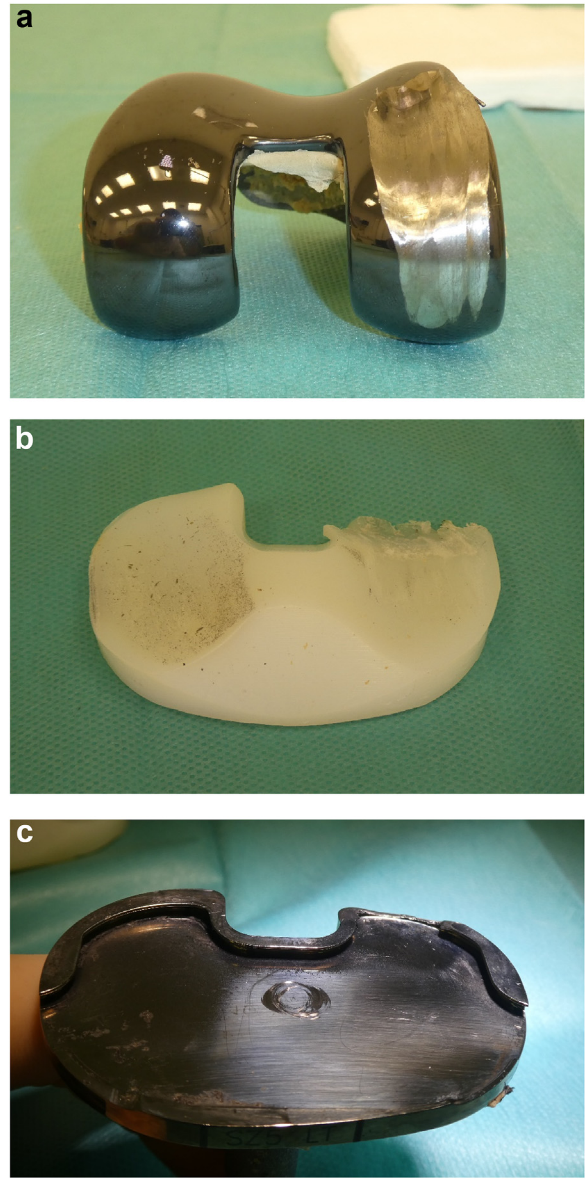

Figure 4. (a-c) Photographs postexplantation reveal a groove in the metal beneath the surface on the lateral aspect of the femoral component (a), massive polyethylene wear on the posterolateral aspect of the insert (b) and a defect of the posterolateral tibial plateau (c).

scratching of the femoral component, leading to the removal of its oxidized layer at the medial condyle as a consequence of possible instability. Similar to our case, they observed the presence of abundant black metallosis. However, in contrast to our findings, this case did not exhibit the characteristic arthrogram on radiographs with ventrally removable metallosis.

In a further publication by Purcell et al. [20], the authors described the extrusion of oxidized zirconium particles with extraarticular extravasation following an unsuccessful TKA but to a much lesser extent than in the present case and others cited without breaking through the oxidized layer. Notably, this study deviates from ours and others, as the authors observed only minimal wear on the articular side of the femoral condyles and did not report any failure of the polyethylene component.

Malalignment has the potential to disrupt normal load distribution, thereby influencing the wear pattern of the endoprosthesis [21]. A postoperative full-leg stance radiograph of our case documented a slightly residual valgus axis of 3 degrees (Fig. 1). Particularly in combination with an imbalance in the mediolateral direction, characterized by a residual lateral contraction and medial joint laxity, it may have further compounded the issue, resulting in persistent valgus alignment and premature wear of the posterolateral insert due to heightened stress and shear forces [22].

Furthermore, sagittal instability due to a posterior cruciate ligament insufficiency, which cannot be ruled out retrospectively in the present case, can also favor abrasion. The predominantly posterolateral polyethylene wear would correspond to this mechanism. To prevent this situation, the posterior cruciate ligament needs to be carefully inspected when primarily implanting TKA,

Figure 5. Radiographs in 2 planes after explantation and implantation of a mobile PMMA spacer, revealing a residual pseudotumor in the popliteal region. PMMA, polymethyl methacrylate.

and in case of an insufficiency a posterior-stabilized design should be used [23].

At this point, another possible failure mechanism must be mentioned that is not based on secondary damage to the OXINIUM surface in the context of excessive polyethylene wear. Damage to the OXINIUM surface, which can occur by accident intraoperatively, can also lead to increased polyethylene abrasion due to the resulting surface roughness [24].

Furthermore, third-body wear, exemplified by any remaining polymethyl methacrylate cement, emerges as another plausible contributing factor [25]. This could have damaged the polyethylene insert as well as the OXINIUM surface, precipitating the unusually distinctive and rapid wear observed with subsequent contact of the metallic components. Notably, in the 3-month postoperative radiograph from 2010, no remnants of polymethyl methacrylate cement were detectable.

Highlighting the critical role of proper surgical techniques, the discussion underscores the significance of accurate sizing, alignment, ligament balancing and fixation of OXINIUM components to optimize wear performance. Any deviations from recommended procedures are identified as potential contributors to increased wear.

Figure 6. Radiographs in 2 planes after removal of the popliteal pseudotumor.

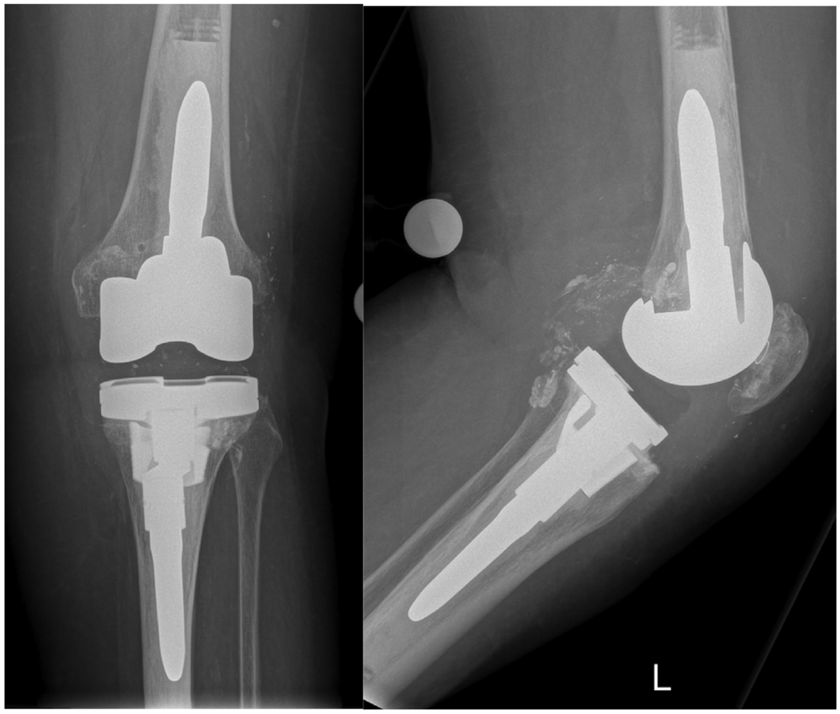

Figure 7. Radiographs in 2 planes 1 year after revision arthroplasty.

Summary

In conclusion, this case serves as a crucial reminder of the intricate interplay between patient-specific factors, surgical techniques, and implant-related considerations in joint replacement procedures. The complexity of wear-related complications underscores the ongoing need for meticulous clinical monitoring, adherence to best practices, and continuous advancements in orthopaedic research to enhance the long-term success of joint arthroplasties, especially when using newer materials. With respect to OXINIUM components, it is crucial to avoid damaging the oxidized surface to prevent severe complications. Furthermore, the long-term effects of OXINIUM abrasion in the form of third-body wear remain unclear and require close monitoring of affected patients.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101479.

Informed patient consent

The author(s) confirm that written informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

CRediT authorship contribution statement

Marius Ludwig: Writing – original draft, Visualization, Data curation. **Martin Faschingbauer:** Writing – review & editing, Resources, Conceptualization. **Heiko Reichel:** Writing – review & editing, Validation, Supervision, Conceptualization. **Tobias Freitag:** Writing – review & editing, Resources, Conceptualization.

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